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APPARATUS FOR REGULATING CURRENT IN MOVING-BOUNDARY EXPERIMENTS

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The measurement of transference numbers by the moving-boundary method depends ultimately upon the passing of a constant current of precise value for a known period of time through a definite volume of the moving-boundary cell. Since the resistance is continually changing during an experiment, the maintenance of a constant current is the most difficult of the variables to control.

The early investigations were carried out by hand regulating the current, either by gradually increasing the applied potential or by decreasing a series resistance.[1] The original apparatus of MacInnes and co-workers[2] and the subsequently modified form[3] have been used for much of the work done in the field of transference-number measurements. Their devices are, however, subject to some error introduced by vibrations. Bender and Lewis[4] have suggested a fairly simple arrangement for providing constant current in which the current flowing through the cell is also the plate current of a pentode tube, the magnitude of the current being controlled by a grid bias. Occasional hand adjustment is still necessary, nevertheless. Carson[5] and Spiro and Parton[6] have also described current regulators of a similar type.

The purpose of this paper is to describe an apparatus which incorporates some of the ideas of Bender and Lewis but which is independent of any regulation whatsoever during experiment. It is not difficult to assemble, is oblivious to vibrations, and the form described is capable of maintaining constant currents with an average deviation of about 0.04% from any desired value between 2 and 10 ma.

The entire apparatus comprises a half-wave voltage-regulated power supply with 150-, 300-, and 450-v taps (Fig. 1) and a modified Micromax (Leeds and Northrup Model C) which incorporates the high-transconductance tube of the Bender and Lewis device. It should be mentioned in passing that, since the peak voltage output of the power-supply transformer is not much greater than 450 v, the drop across the choke is enough to make the VR tube work; hence no additional series resistance is used.

The modifications to the Micromax are as follows: the control switch and slide-wire assemblies for the external circuit are removed, and the shaft is cut back and insulated to accommodate a GR potentiometer as shown in Fig. 2. The lead running from the contact arm of the balancing slide wire to the terminal TC+ is removed, as are the black wires connecting the slide-wire assembly to a resistor and a brass tie point. (The resistor also is connected by a black wire to the standardizing slide and carries, in addition, two red-and-white trace wires; the brass tie point has one additional connection – a green-and-white trace wire.)

In Fig. 3, the resistor string between A and B (100 Ω, 200 Ω, and 2 Ω) replaces the Micromax slide wire, A being the resistor lug and B the brass tie point from which the black wires were removed as described above.

One side of a dpst switch is inserted into the lead between the fuse and the Micromax motor terminal. The other side of this switch is SW in Fig. 3. The input of the 6.3-v filament transformer (D and D′) is tied across the motor terminals. A 0.75-amp fuse replaces the 0.45-amp fuse supplied.

Lead C is the existing yellow-and-blue trace wire which runs to the galvanometer circuit. F is a current-shunt resistor – in this case, 72 ohms to allow operation over a range from 2 to 10 ma. E is the power supply and should be of the voltage required to obtain the desired current through the moving-boundary cell.

To reduce the tendency of the Micromax to "hunt," the sliding contact is caused to rotate, not by the shaft directly, but by means of a yoke connected to the shaft and fitted loosely around a stud as shown in Fig. 4. Under these conditions, if the Micromax overshoots and reverses itself, the play in the yoke prevents transmittal of the

[1] D. A. MacInnes and L. G. Longsworth, *Chem. Rev.* 11, 188 (1932).

[2] D. A. MacInnes, I. A. Cowperthwaite, and K. C. Blanchard, *J. Am. Chem. Soc.* 49, 1710 (1927).

[3] L. G. Longsworth and D. A. MacInnes, *J. Opt. Soc. Amer.* 19, 50 (1929).

[4] P. Bender and D. R. Lewis, *J. Chem. Ed.* 24, 454 (1947).

[5] W. N. Carson, *Anal. Chem.* 22, 1565 (1950).

[6] M. Spiro and H. N. Parton, *Trans. Faraday Soc.* 48, 263 (1952).

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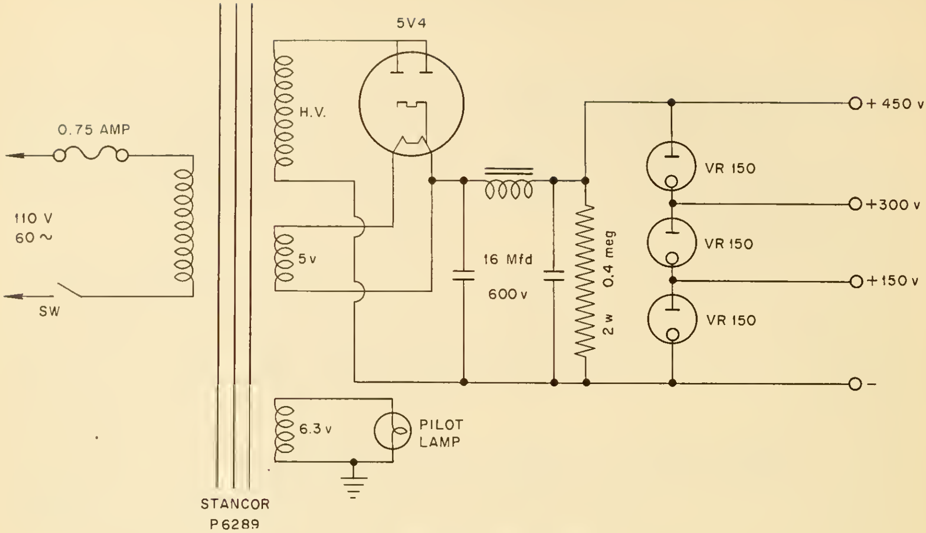

Fig. 1. Stabilized D-C Power Supply.

full travel to the slider; the resulting effect is about one-fifth the full travel of the shaft. Except under the most extreme conditions, this reduced travel will not permit overshooting in the opposite direction and suffices simply to bring the setting nearer to the correct operating point. Usually the next increment of travel is small enough to bring the Micromax readily to balance. Since this yoke mechanism operates only during reversals of direction, it does not affect the operation when the Micromax is responding to any large changes involved in bringing the circuit back to balance.

To permit estimation of the current, voltage, and resistance during transference-number measurements (and during the evaluation of the current regulator), a meter box was assembled containing suitable resistances, shunts, and a switch to give readings within 1% of the true value at any time. The arrangement is shown in Fig. 5a. The meter shown is a 100-μa G-E type D-058 which is easily read to within 1%. The microampere movement minimizes the shunt current around the cell when voltage measurements are being made. The particular choice of resistors gives full-scale readings of 500 v or 10 ma on the meter; the corresponding signals to the potentiometer are 50 and 100 mv, respectively.

The terminals + and – shown in Fig. 5*b* allow the use of an external potentiometer (volt box) across built-in precision resistors for more precise measurements than can be obtained with the meter itself.

Table 1 shows typical values for several currents as the resistance is changed over a considerable range.

Table 2 includes various values for currents and the corresponding resistance ranges of the instrument.

From Table 2, it is seen in the case of a 5-ma current with the 450-v supply, for example, that the resistance may be changing as much as from 1,500 to 85,000 ohms. Since constant currents of from 3 to 6 ma were required during resistance changes of from about 5,000 to 50,000 ohms, the circuits were designed to handle them. Figure 6 shows the operating ranges for various voltage supplies. Actually, the apparatus can be made operable over almost any desired range by suitably changing resistances of the circuit and the potential divider.

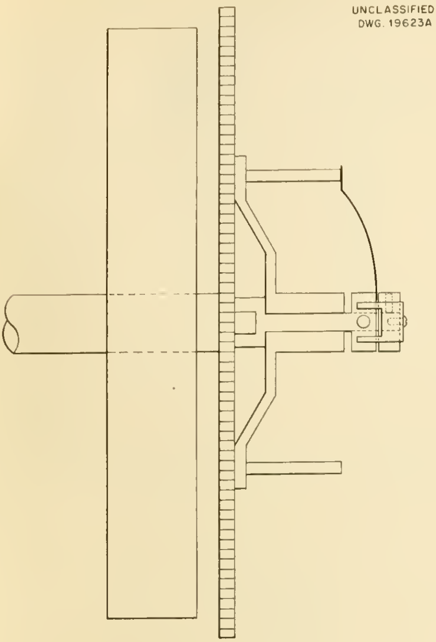

Fig. 2. Modified Potentiometer.

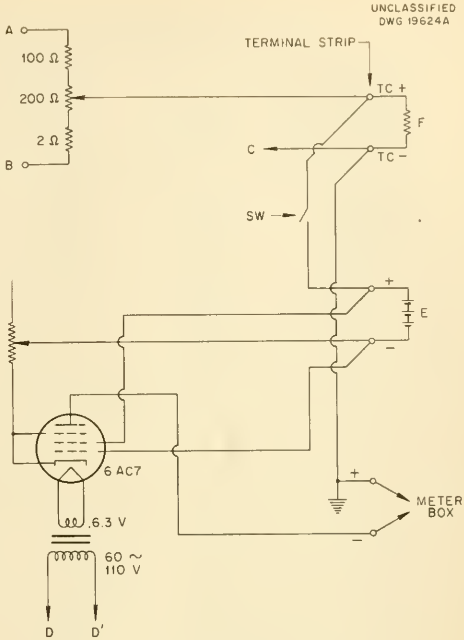

Fig. 3. Constant Current Supply.

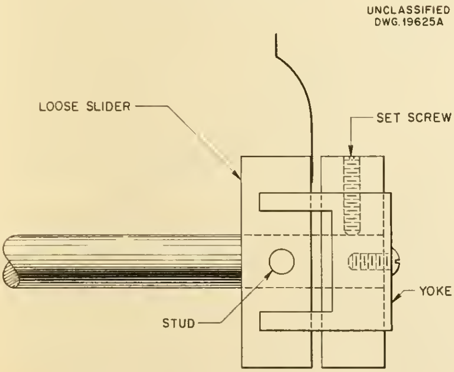

Fig. 4. Detail of Modified Potentiometer, Fig. 2.

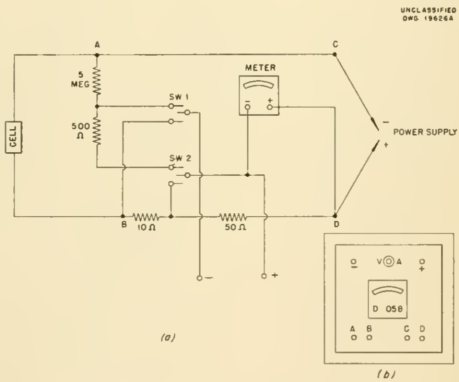

Fig. 5. Ammeter-Voltmeter Box.

Table 1. Variations in Current Values with Changes in Resistance

150-v Supply, Resistance (ohms $\times 10^{-3}$)	Current (ma)	300-v Supply, Resistance (ohms $\times 10^{-3}$)	Current (ma)	450-v Supply, Resistance (ohms $\times 10^{-3}$)	Current (ma)
		77.7	3.052	77.7	5.032
57.4	2.027	57.4	3.052	57.4	5.035
43.0	2.027	43.0	3.055	43.0	5.032
35.0	2.027	35.0	3.055	35.0	5.037
25.3	2.030	20.3	3.057	20.3	5.037
15.0	2.027	15.0	3.057	15.0	5.035
5.0	2.027	5.0	3.055	5.0	5.035

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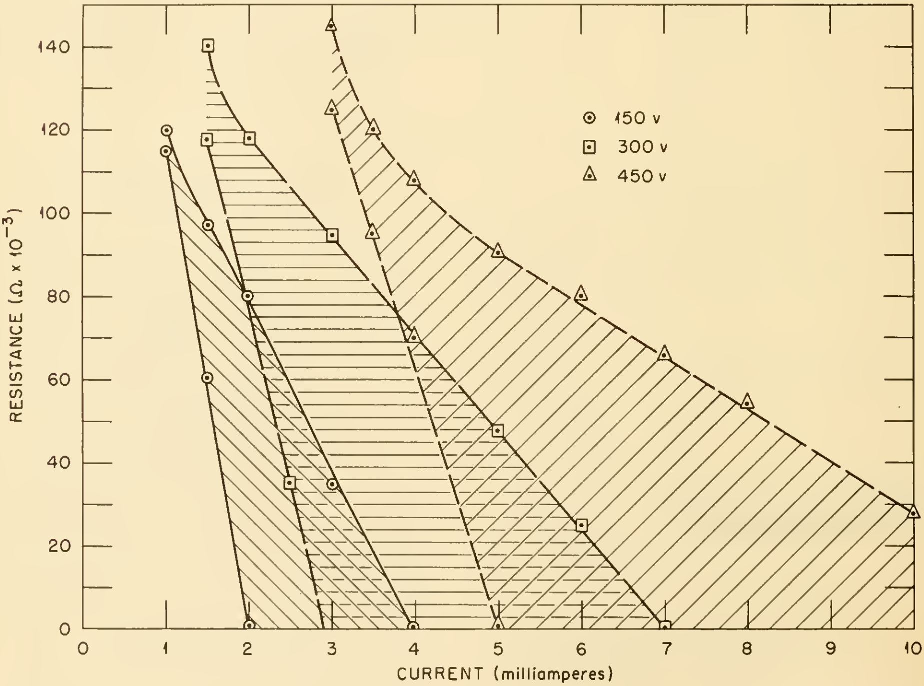

Fig. 6. Approximate Maximum and Minimum Resistances at Various Constant Currents.

Table 2. Approximate Resistance Ranges of the Instrument for Various Current Values

Voltage Supply (v)	Current (ma)	Approximate Resistance Range (ohms $\times 10^{-3}$)	Voltage Supply (v)	Current (ma)	Approximate Resistance Range (ohms $\times 10^{-3}$)
150	2	1.5–62	450	4	3–104
300	3	1.5–95	450	5	<1.5–85
300	4	1.5–67	450	6	<1.5–70
300	5	1.5–45	450	7	<1.5–58
			450	9	<1.5–40